

LiGrip SE

FAQ



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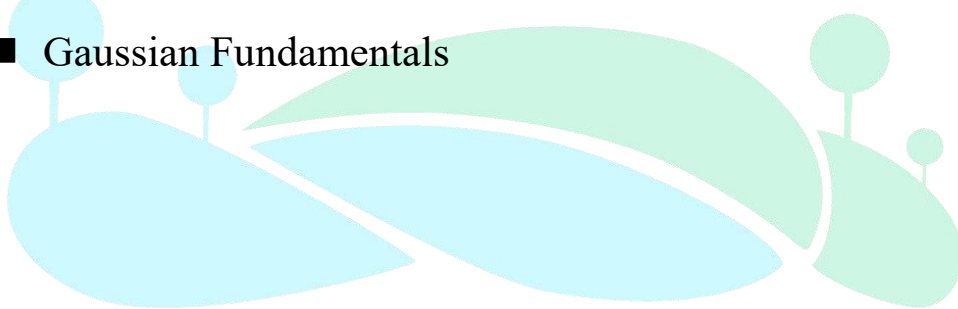
Note: This FAQ addresses common software and hardware issues, covering most problems encountered from data acquisition to processing. If this FAQ does not address your specific issue, please contact after-sales or technical support for assistance.

Prerequisites: This FAQ is not an operation manual. Before reading, you should possess a basic understanding of data acquisition and processing. At a minimum, you should have read the device's operating instructions and be capable of performing basic data acquisition and processing.

01 Basic Knowledge

This chapter introduces:

- Basic SLAM Knowledge
- LiDAR Basics
- Surveying Fundamentals
- Gaussian Fundamentals



1. Basic SLAM Knowledge

Basic knowledge of SLAM provides a fundamental understanding of the equipment and software you will be using. With this foundational understanding, you will better comprehend the process and achieve the desired data results.

1.1. The Principle of SLAM

SLAM, Simultaneous Localization and Mapping. Starting from an unknown location in an unknown environment, SLAM uses sensor observations to determine its position, attitude, and trajectory, and builds a map based on this information. During movement, the system locates itself using position estimation and the map. Real-time localization and map building are interdependent.

In simple terms, multiple frames of point cloud data are collected during movement. The SLAM algorithm analyzes and identifies these point cloud data frame by frame. If object A is scanned in both the current and subsequent frames, the point cloud data for object A from both frames are analyzed to confirm it is the same object. The data from the two frames are then stitched together accordingly. The entire map is constructed by piecing together frames in this manner.

Consequently, if the SLAM algorithm's recognition is poor, it may incorrectly identify object A in the previous frame and object B in the subsequent frame as the same object, resulting in a misaligned stitch that deviates from reality.

This also necessitates the presence of sufficient feature points in the environment. On a completely featureless, flat surface, it is impossible to stitch the two frames together. They can only be stacked, causing the point cloud image to thicken, the three-dimensional image to lose clarity, and the quality to degrade.

1.2. What is a Feature?


The fundamental principle of the SLAM algorithm is to match Feature points between different frames, thereby determining the position of the Device and subsequently generating surrounding map information. Therefore, in areas with a high density of Feature points, such as street facades or underground parking garages, SLAM demonstrates greater stability. In environments with weak textures, such as smooth Tunnels, particularly open spaces, or deserts, the

stability of SLAM decreases, resulting in reduced reliability of the acquired Data.

1.3. Scenarios Unsuitable for SLAM

Unsuitable scenarios refer to situations where SLAM cannot obtain effective Features, or where the Features are too similar to each other.

Unsuitable scenarios			
Serial number	Description	Scene image	Remarks
1	Objects with indistinct features		For example: a smooth tunnel
2	Open area		For example: open flat ground or road Using an O2 Series device can address such scenarios
3	Heavy vehicle or pedestrian traffic		National highways or bustling commercial streets with

			<p>high pedestrian flow</p> <p>Using an O2 Series device can address such scenarios</p>
4	<p>Swaying leaves and flowers</p>		<p>Parks or forested areas on windy days</p> <p>Using an O2 Series device can address such scenarios</p>

1.4. What is Accumulated Error?

Since SLAM mapping relies on stitching together multiple frames of raw laser point cloud data, the stitching error accumulates over time and distance.

Accumulated error is generally calculated as N%, meaning that after walking 1,000 meters in a straight line or in a scenario without loop closure, the 3D distance between two identical objects is N meters. The smaller the value of N, the better the SLAM algorithm.

There are three methods to eliminate or mitigate the effects of accumulated error: loop closure, GNSS acquisition, and GCP acquisition.

In scenarios with weak features or no features, the accumulated error in SLAM will be greater than in environments with normal features.

1.5. What is Loop Closure?

1.5.1. The function of loop closure

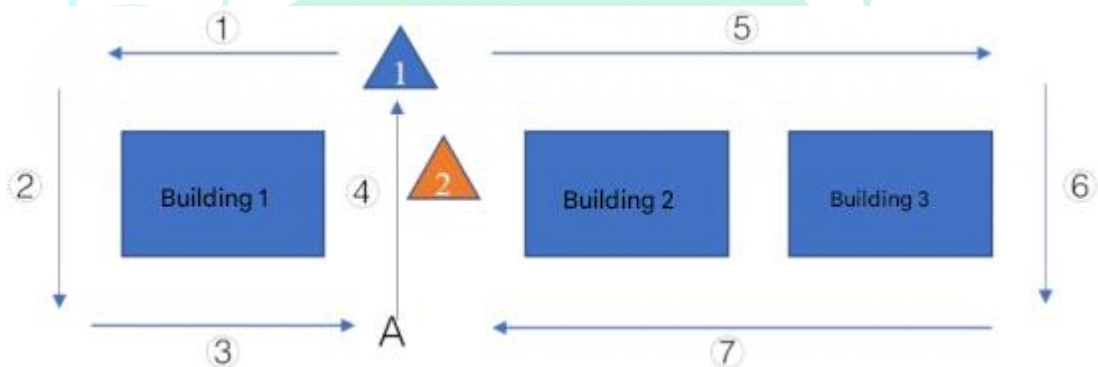
Loop closure is a method to improve data accuracy in environments without GNSS or with weak GNSS signals.

1.5.2. The concept of loop closure

Loop closure, as the name implies, refers to forming a closed loop (which can be simply understood as returning to a place you have previously visited). As time and distance increase, accumulated error grows, making it necessary to introduce external variables for correction, such as GNSS or loop closure. When loop closure is present, it is equivalent to introducing an external variable from the physical world. At this point, the program can utilize this variable to eliminate accumulated errors.

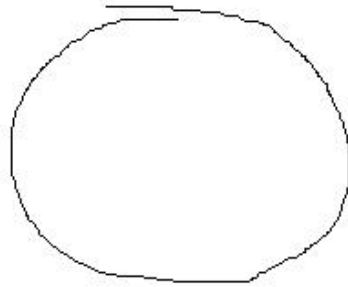
1.5.3. How to correctly perform loop closure

Loop closure can significantly enhance the reliability and accuracy of the data. Therefore, whenever conditions allow, it is advisable to perform loop closure whenever possible.



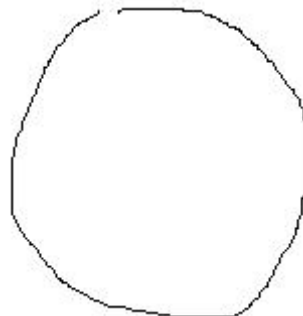
As shown in the figure above, buildings 1, 2, and 3 are the objects to be scanned. It is recommended to begin scanning from 1 rather than from 2. Before starting the scan, plan the scan path. According to the above guidelines, feasible scan paths for this scenario are ①②③④⑤⑥⑦ or ⑤⑥⑦④①②③.

During loop closure, it is necessary to walk an additional 5–10 meters to ensure the program correctly recognizes the loop closure (as shown in the figure below).

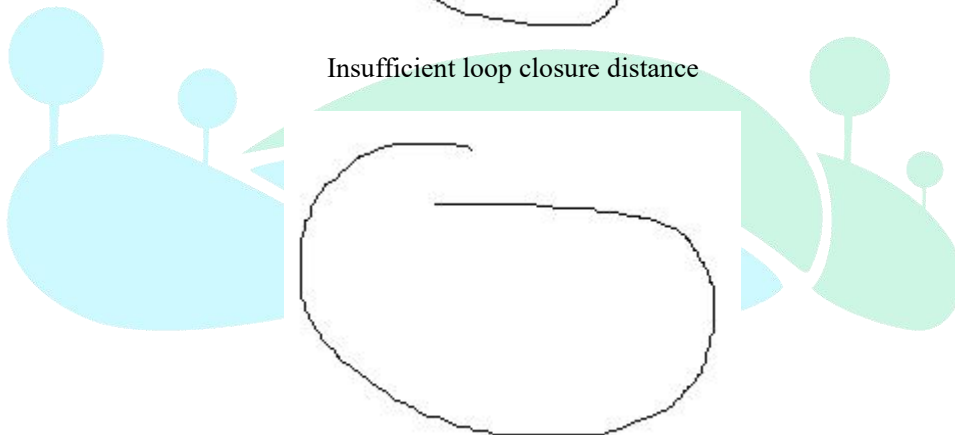


Correct loop closure

The following are examples of incorrect loop closure:



Insufficient loop closure distance



The distance between the start and end points is too great

1.6. What is a control point?

Control points are another method to eliminate SLAM accumulated error and assign absolute coordinates to the point cloud. The denser the control points, the higher the accuracy of the point cloud.

We recommend a control point density of 50–100 meters.

1.7. What is SLAM Initialization

There are two concepts:

- ① Initialization refers to the synchronization of all device hardware in the system;
- ② The process of SLAM base map construction. The base map is essential for accurate

SLAM mapping, so be sure to follow the operating manual.

The following precautions should be observed when initializing our company's handheld device:

- ① **Do not point the laser emitter at walls, the ground, the sky, or open areas with few features.**
- ② **Do not perform initialization in areas with heavy pedestrian or vehicle traffic.**
- ③ **When collecting data in tunnels, mine shafts, or similar environments and entering from outside, initialize while facing the entrance.**
- ④ **In standard data collection environments, during initialization, simply point the laser emitter toward the collection scene.**
- ⑤ **Keep the device completely still during initialization. It is recommended to hold it steadily or place it on the ground to prevent unintentional movement during handheld initialization.**
- ⑥ **Ensure that the initialization time is sufficient: the indicator light will change from rapid flashing to slow flashing.**

1.8. What is PPK/RTK?

1.8.1. PPK

PPK (Post-Processed Kinematic) is a high-precision GNSS positioning technology. Unlike RTK (Real-Time Kinematic), which operates in real time, PPK is a post-processed dynamic relative positioning technique. PPK technology allows users to conduct measurements without a real-time data communication link. This means users can collect raw GNSS data in the field and later process this data using precise information from a base station or reference station network, thereby achieving high-precision positioning results.

1.8.2. RTK

RTK GNSS (Real-Time Kinematic Global Navigation Satellite System) is a real-time dynamic measurement technology that provides centimeter-level positioning accuracy using differential GPS (RTDGPS) technology. RTK technology is composed of three parts: the base station (fixed station), the data link, and the rover station (mobile station). The base station receiver continuously observes satellites and transmits observation data and station information to

the rover station via radio. The rover station uses this data to calculate its three-dimensional coordinates and accuracy in real time.

The differences between PPK and RTK are as follows:

Features/Technology	PPK (Post-Processed Kinematic)	RTK (Real-Time Kinematic)
Definition	Post-processed kinematic relative positioning technology.	Real-time kinematic carrier phase differential positioning technology.
Data Processing	Data is processed on a computer after data acquisition.	Processes data from the rover and base stations in real time.
Communication Requirements	No real-time communication link required.	A real-time data communication link is required.
Operating radius	Relatively large, up to over 60 km.	Relatively small, typically 10–15 km.
Environmental adaptability	Suitable for complex environments, with minimal environmental impact.	Certain environmental requirements; may be affected by obstructions.
Accuracy	Can achieve millimeter- to centimeter-level accuracy.	Can achieve centimeter-level accuracy.
Convergence time	No waiting required; post-processed.	Requires time to converge, usually short.
Applicable scenarios	Suitable for scenarios where real-time results are not required.	Applicable to scenarios requiring real-time, high-precision positioning, such as surveying and precision agriculture.
Cost	Lower, no need for real-time	Higher, requires real-time

Features/Technology	PPK (Post-Processed Kinematic)	RTK (Real-Time Kinematic)
	communication devices.	communication and data processing devices.
Flexibility	High, not limited by real-time communication.	Lower, limited by real-time communication and base station location.
Advantages	Suitable for long baselines and complex environments, with no need for real-time communication.	Provides rapid real-time positioning accuracy, suitable for applications requiring immediate feedback.

Our company offers both of the above high-precision positioning methods. You may choose according to your specific needs.

1.9. What is PPK-SLAM/RTK-SLAM?

PPK-SLAM and RTK-SLAM refer to two methods of data source fusion.

Loosely coupled: This refers to fusing GNSS position with SLAM pose. Simply put, GNSS is used to transform the point cloud/trajectory from the SLAM coordinate system to the absolute geographic coordinate system. This involves how to filter GNSS positioning points (since GNSS can sometimes be unreliable); adjusting the fusion weights between SLAM and GNSS; and performing local least squares adjustments.

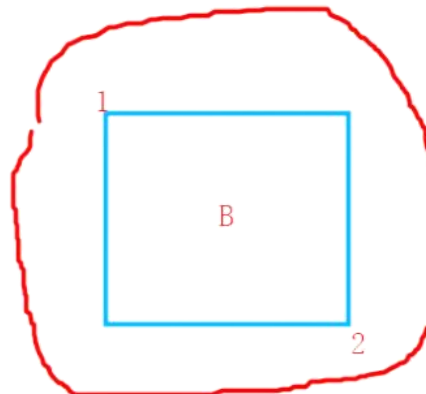
Tightly coupled: refers to the process in which two different data sources mutually optimize each other's raw data, such as using GNSS to participate in SLAM frame matching, or using SLAM's raw observation information to assist with ambiguity resolution. In the future, these two data sources may be directly fused at the hardware level.

1.10. Relative accuracy

For Laser SLAM, relative accuracy refers to the difference between the measured distance of two non-line-of-sight points and the true value. This metric actually indirectly evaluates the overall mapping accuracy of the SLAM process.

What does non-line-of-sight mean? In the diagram below, B represents a building, and points 1 and 2 are either corners of the building or other objects. During handheld SLAM scanning, if

points 1 and 2 cannot be scanned simultaneously, it means these two points are not in line of sight.



1.11. Absolute accuracy

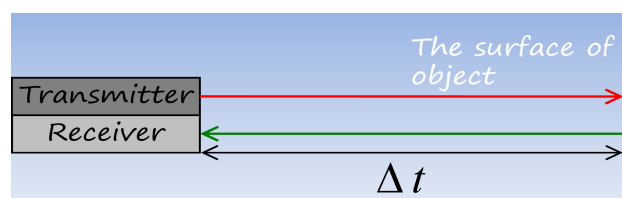
Absolute accuracy refers to the difference between the point cloud with absolute coordinates after mapping and the actual check points. Generally, at least three points are required, and the metric is the mean error in both the horizontal plane and elevation.

2. LiDAR Basics

2.1. LiDAR Principle

LiDAR (Light Detection and Ranging) is a technology for laser detection and ranging. LiDAR uses a laser emitter as the light source and a photoelectric detection sensor as the receiving component. Based on the principle of laser ranging, it measures and records distance and angle to determine the positional information of the target object.

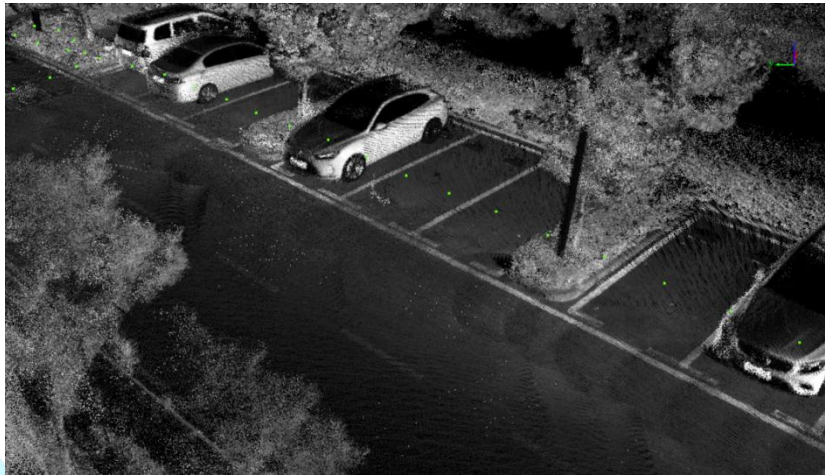
When a light pulse strikes an object and reflects back to the receiver, the travel time is measured. Since the speed of light is known, this travel time can be converted into a distance measurement.



2.2. Intensity

The most direct and significant advantage of LiDAR is its ability to actively acquire three-dimensional coordinate information of target objects. In addition to three-dimensional information, LiDAR is also capable of capturing the reflectivity of objects. The reflectivity

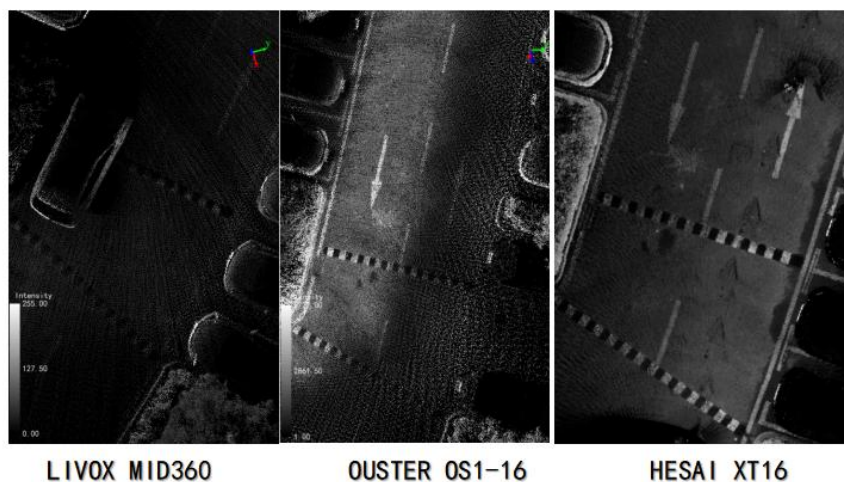
information of an object is represented as intensity in the LiDAR point cloud (as shown in the figure below, where white indicates high intensity and black indicates low intensity). We can imagine that when a car is driving at night, the headlights illuminate certain road signs, reflective strips, and crosswalks. The reflectivity of these signs stands out in sharp contrast to the road surface.



Intensity is influenced by the material, roughness, and lighting conditions of the object. As a result, many point cloud post-processing software applications use intensity information for automatic extraction and mapping.

The performance of different laser emitters varies, and the quality of their intensity differs accordingly. Below are the intensity differences among three common types of laser emitters.

At different times, factors such as rain, dust, and the angle of the sun can all affect intensity values.



2.3. Reflectivity

Reflectivity refers to the ratio of the intensity of the laser signal reflected from an object's surface to the intensity of the original emitted signal. This ratio can be used to assess the reflective properties of an object's surface and is critical to the performance and application of LiDAR systems. The influencing factors include the following:

- ① **Surface material:** Different materials have different reflectivity. For example, metals typically have high reflectivity, while black plastics may have low reflectivity.
- ② **Surface roughness:** Smooth surfaces tend to produce specular reflection, while rough surfaces may result in diffuse reflection.
- ③ **Color:** Dark-colored objects typically absorb more light and exhibit lower reflectivity.
- ④ **Observation angle:** Variations in the angle of incidence and observation can affect reflectivity.

Material type	Reflectivity range (%)	Description or common applications
Metal	70 - 95	High reflectivity, commonly found in automobiles and building exteriors.
Concrete	20 - 40	Medium reflectivity, commonly found in building structures and sidewalks.
Asphalt	10 - 30	Low to medium reflectivity, commonly found on road surfaces.
Vegetation	5 - 20	Low reflectivity, depending on the type and density of the vegetation.
Water	0 - 10	Very low reflectivity, depending on the turbidity and surface fluctuations of the water.
Soil	5 - 15	Low reflectivity, depending on the soil type and moisture content.

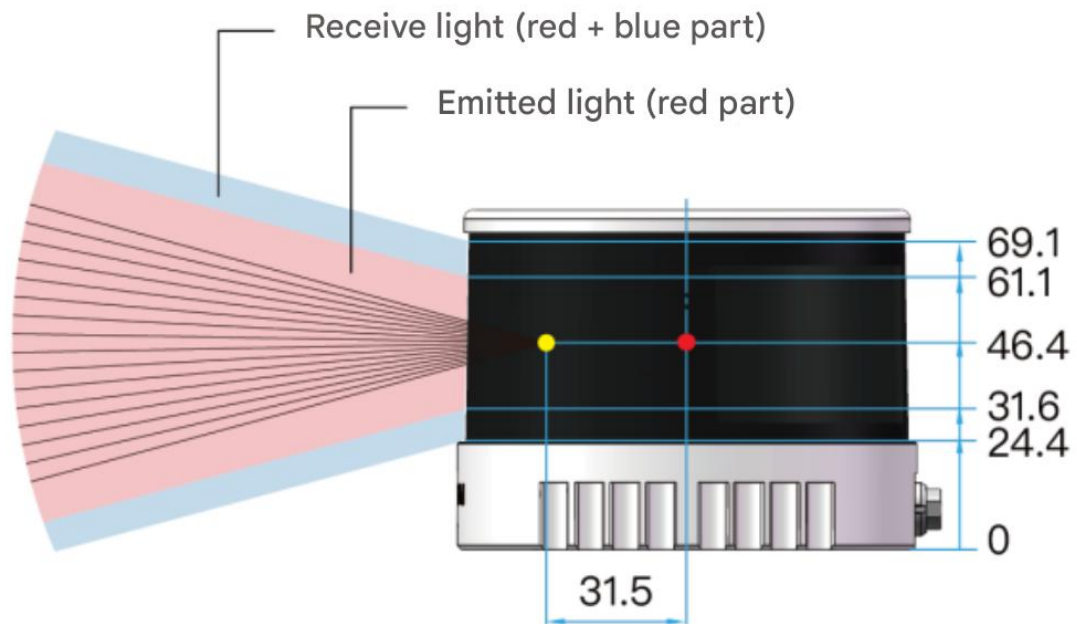
Material type	Reflectivity range (%)	Description or common applications
Wood	10 - 30	Medium reflectivity, depending on the wood species and surface treatment.
Plastic	5 - 50	Reflectivity varies greatly, depending on the type and color of the plastic.
Glass	5 - 70	Depending on the cleanliness and surface roughness of the glass, it may exhibit high reflectivity or transparency.
Snow	80 - 95	High reflectivity, depending on the purity and degree of compaction of the snow.
Ice	40 - 80	High reflectivity, which depends on the transparency and surface condition of the ice.

Objects with higher reflectivity are easier to detect and will also exhibit higher intensity values.

2.4. Rangefinding

Below is the XT16 laser emitter manual, where its ranging capability is described.

Distance measuring ability ①	80m@10% reflectivity (channels 5~12)
	50m@10% reflectivity (channels 1~4, 13~16)



80m@10% reflectivity indicates that this laser emitter has a ranging capability of 80 meters on materials with 10% reflectivity.

For mechanical rotating LiDAR, the beams closer to the center (XT16: 5-12) have stronger ranging capability.

The capability of laser ranging is also affected by ambient lighting. As shown in the figure below, the test environment for the XT16 laser emitter's long-range measurement is as follows.

- Test conditions: ambient illumination 100 klux, detection probability over 90%

During the daytime, ambient illuminance varies depending on the weather, time, and location. On a clear sunny day, the illuminance of sunlight directly hitting the ground is about 100 klux. Illuminance in cloudy or shaded areas is relatively lower. For example, in a shaded area on a sunny day, the illuminance is about 10 klux. Near a north-facing indoor window, the illuminance is about 2,000 lux. For outdoor activities to prevent myopia, an illuminance above 1,000 lux is beneficial, and the effect becomes more significant when it exceeds 3,000 lux.

Therefore, if you want to test the laser emitter's ranging capability to its limits, performing the test at night and targeting an object with the highest reflectivity will greatly enhance the ranging capability.

2.5. Spot

LiDAR measures distance by emitting laser beams toward objects. However, the laser is not

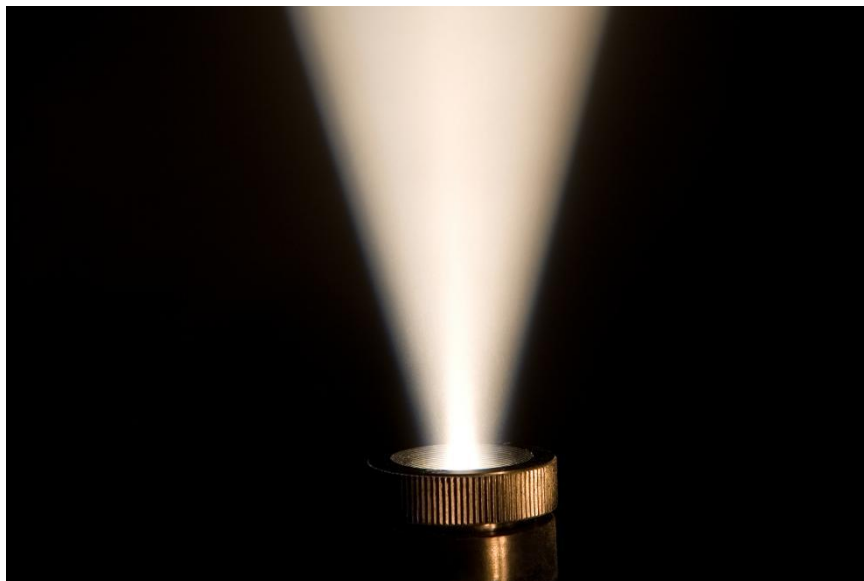
without size; it has a certain diameter. This laser forms a spot on the object, as shown in the figure below (captured by an infrared camera). The white dot represents the spot.



2.5.1. What is the effect of the spot?

You can think of the spot as similar to a flashlight:

- ① The farther the flashlight is from the object, the wider the illuminated area becomes, and the larger the spot.
- ② The higher the flashlight's power, the brighter the illuminated area.
- ③ The more focused the flashlight beam, the narrower the illuminated area, but the brighter and farther the illuminated target.



From the above, it can be concluded that

- ① A larger spot is not necessarily better; in fact, a smaller spot illuminates objects more

effectively. This means that a LiDAR with a smaller spot is actually of higher quality, offering stronger ranging and penetration capabilities.

- ② The stronger the emission capability, the greater the irradiation distance.

2.5.2. Comparison of spots from different laser emitters

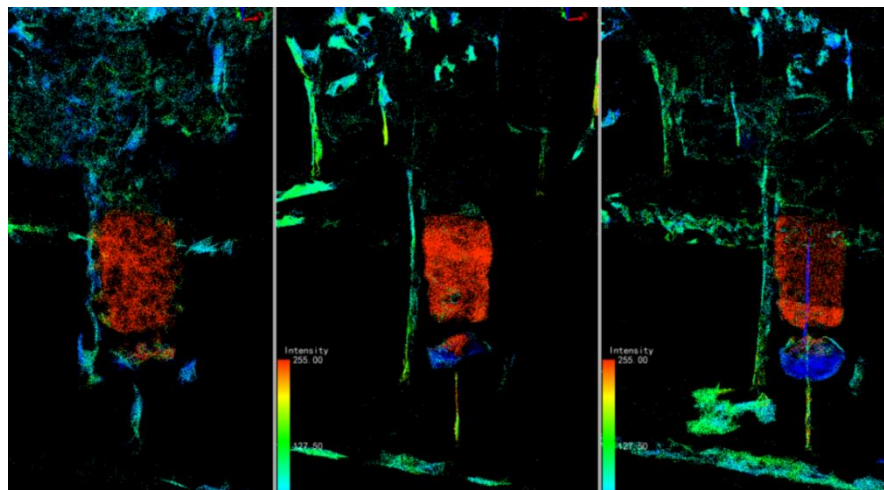
Below is a comparison of spots from different laser emitters. For other distances, the spot size can be calculated proportionally.

Table 1 Comparison of spot sizes from different laser emitters

Laser type	Spot size	Spot shape	Spot size at 20 meters (meters)
Mid 360	0.1°*1°	Long elliptical	0.04*0.35
XT-16/XT32	0.09°*0.13°	Elliptical, nearly circular	0.03*0.04
XT32M2X	0.13°*0.15°	Elliptical, nearly circular	0.04*0.05

2.5.3. The spot represents the structural resolution of the object.

The spot is projected onto the object, the distance is calculated from the return, and a 3D map is generated using the SLAM algorithm. The size of the spot determines the minimum unit of distance that the laser calculation unit can measure; therefore, the smaller the spot, the clearer the object's structure. The following image illustrates the differences in how three types of laser emitters represent signboards (Mid 360 XT-16 XT32M2X).



O1-LITE provides a poor representation of the physical structure of the signboard; the bracket and reflector are not fully depicted. Both H120 and H300 are generally represented; however, due to the lower point density of H120, its completeness is inferior to that of H300.

3. Surveying Fundamentals

Since surveying encompasses a broad range of topics, I will provide only the fundamental explanations of commonly encountered surveying principles relevant to handheld SLAM operations.

For details on how MLS performs coordinate system transformations, please refer to the MLS manual.

3.1. WGS84 Earth-Centered, Earth-Fixed (ECEF) Coordinate System

The WGS84 (World Geodetic System 1984) coordinate system is an internationally adopted Earth-Centered, Earth-Fixed (ECEF) coordinate system, with its origin at the Earth's center of mass.

3.2. Local Coordinate System

Some cities in China, to meet the needs of production and construction or for certain major projects (mostly for deformation control), have established their own independent coordinate systems.

Generally, independent coordinate systems are established using the following three methods:

① Changing the central meridian;

Since deformation increases with distance from the central meridian, adjusting the meridian to be closer to the local area can reduce the degree of deformation.

② Change projection height

The default projection height for CGCS2000 is the ellipsoid surface. In some high-altitude regions, maintaining the projection on the ellipsoid surface can lead to length distortion.

Therefore, changing the projection height is often adopted.

③ Coordinate translation or four-parameter transformation

Coordinate translation involves adding a constant to the east and north directions, while the four-parameter transformation includes rotation, translation, and scaling.

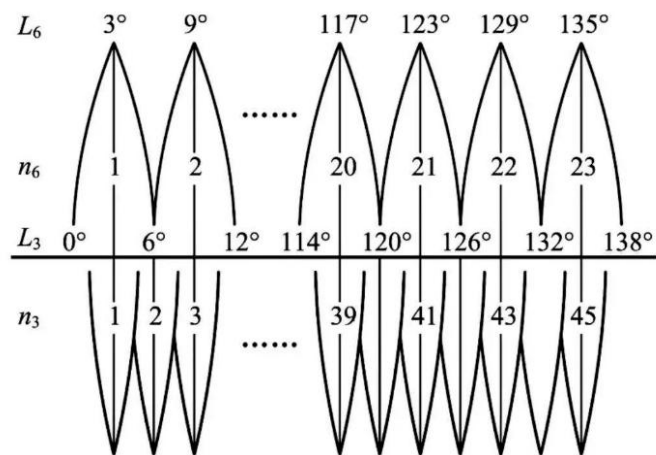
3.3. Gaussian Projection / Transverse Mercator Projection

The Gaussian/ Transverse Mercator projection is a commonly used conformal projection in China and Southeast Asian countries. During the projection process, angles are preserved, thereby

maintaining shape similarity within small areas. Although the Gaussian projection maintains shape similarity within small areas, there is still some distortion over large areas, especially at the edges of the projection zone. Therefore, the Gaussian projection is generally divided into zones to control projection distortion.

3.3.1. Zoning

For large-scale mapping (1:2000, 1:1000, 1:500), the Gaussian projection always uses the 3° zoning method. Small-scale maps generally use the 6° zone (which we rarely use).



Zone number for a 3° zone = $(\text{longitude} + 1.5^\circ) / 3$, rounded down

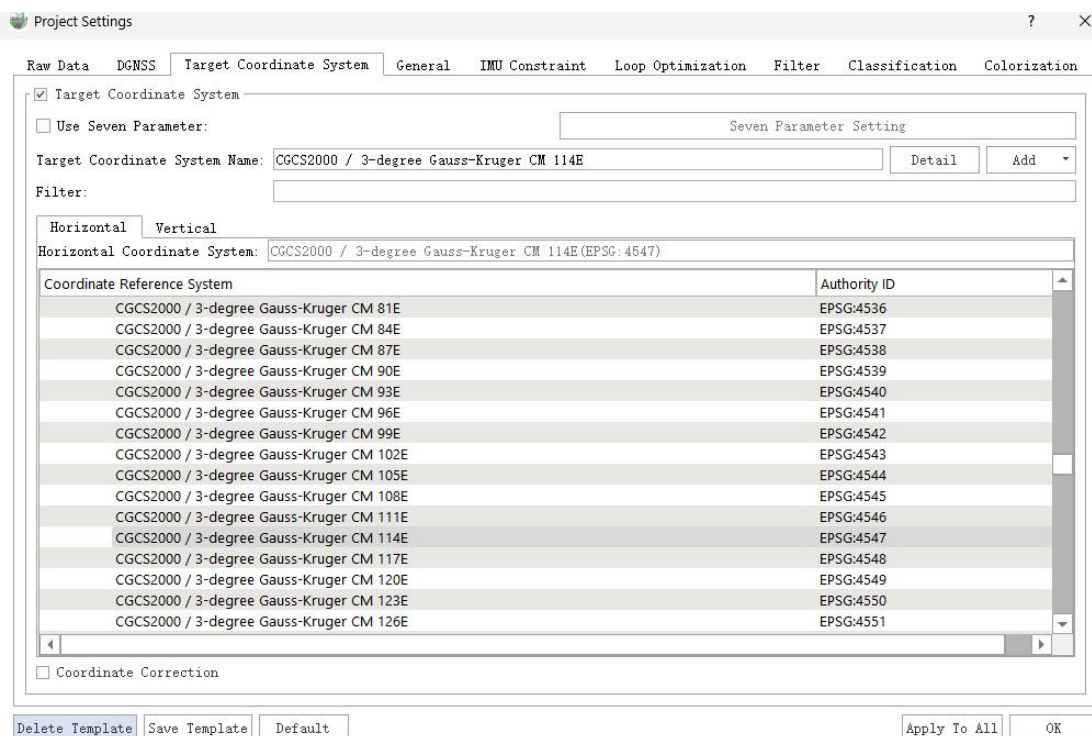
Central meridian of the 3° zone = zone number of the 3° zone $\times 3$

For example, calculating the central meridian of the 3° zone for a location at longitude 112.2°:

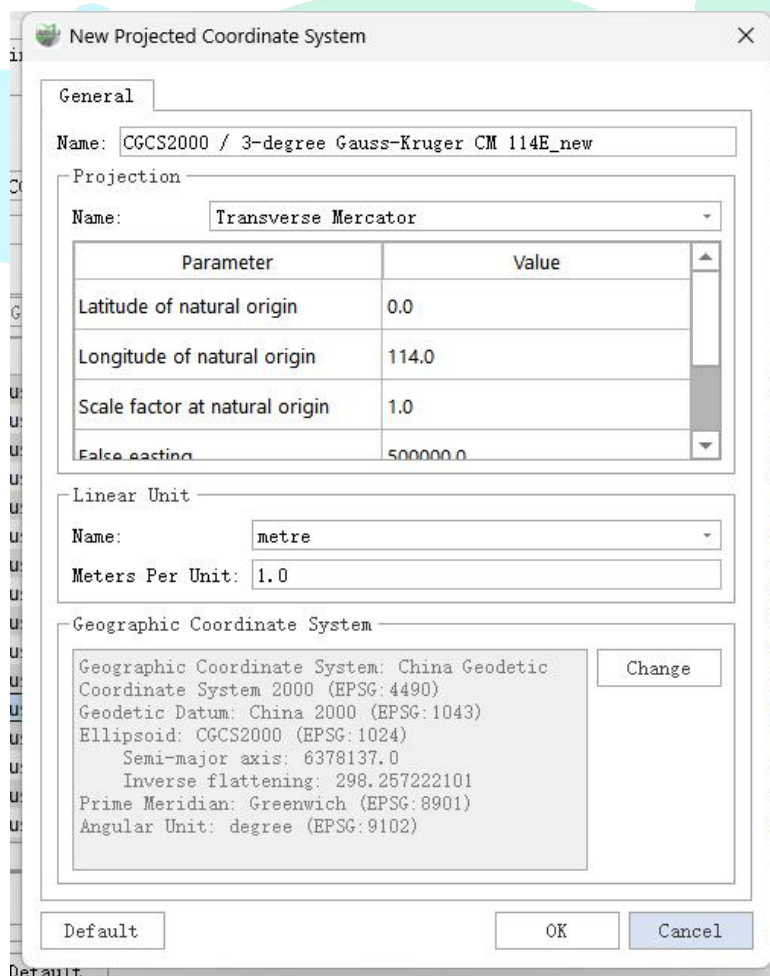
$$\text{Zone number} = (112.2 + 1.5) / 3 = 37.9, \text{ rounded down} = 37$$

$$\text{Central meridian} = 37 \times 3 = 111^\circ$$

Note: For certain coordinate values, the zone number may be added to the east coordinate. In such cases, be sure to confirm with the client.



3.3.2. Projection parameters



- ① Name: Projection method Transverse Mercator
- ② Latitude/Longitude of natural origin: Origin latitude and longitude

The origin of the coordinate system is located at a specific latitude and longitude. Generally, for Gaussian projection, both are 0, and the central longitude is used.

- ③ Scale factor at natural origin: Origin deformation scale

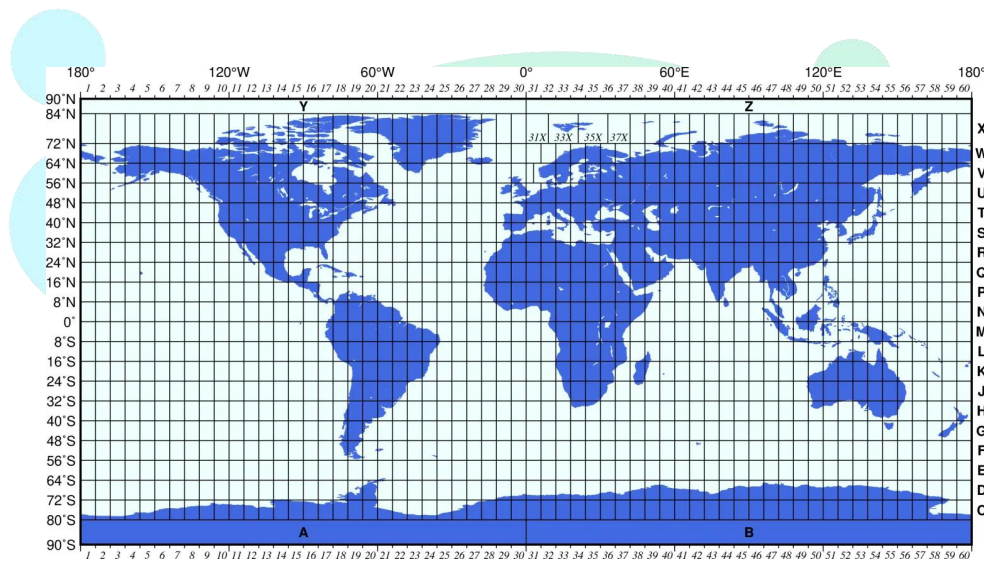
For Gaussian projection, the value is 1.

- ④ False easting/northing: Easting/Northing offset constant

By default, the false easting is 500,000 and the false northing is 0. The purpose of adding these constants is to ensure that the coordinates are non-negative.

3.4. UTM Projection

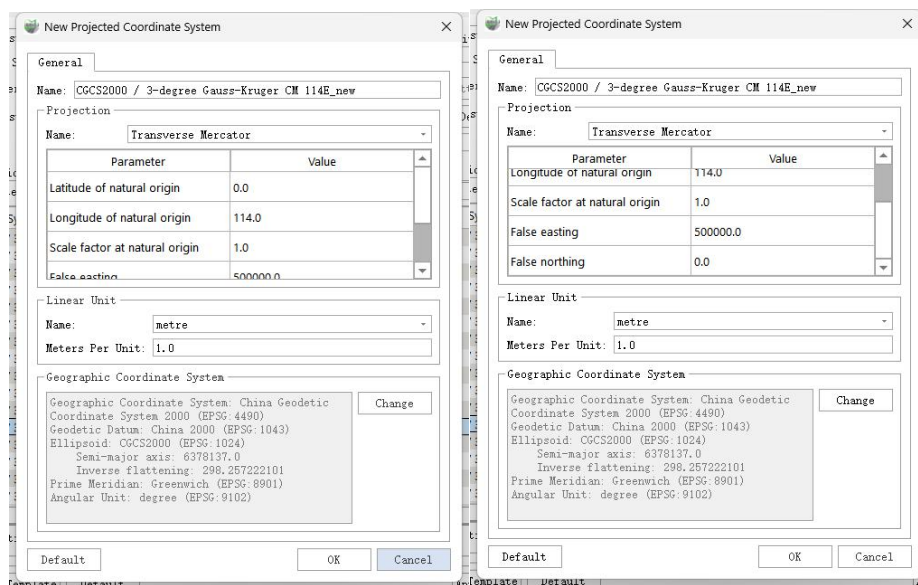
Universal Transverse Mercator projection: The Universal Transverse Mercator projection is a transverse conformal cylindrical projection (universal transverse mercator projection).



3.4.1. Zoning

Zones are divided every 6° (there is no 3° zoning), starting from 180°E (or 180°W), counted from west to east. Globally, the area between 80°S and 84°N is divided into 60 zones. Each zone has its own central meridian with a specific offset. The central meridian of zone 1 is -177°. The 0° meridian serves as the boundary between zones 30 and 31, with the central meridians of these two zones being -3° and 3°, respectively.

3.4.2. Projection parameters



- ① Name: Projection method Transverse Mercator
- ② Latitude/Longitude of natural origin: Origin latitude and longitude

The origin of the coordinate system is located at a specific latitude and longitude. Generally, for Gaussian projection, both are 0, and the central longitude is used.

- ③ Scale factor at natural origin: Origin deformation scale

The UTM Projection uses a scale factor of 0.9996.

- ④ False easting/northing: Easting/Northing offset constant

The default False Easting is 500,000, and the False Northing is 0. In the southern hemisphere, the False Northing is 1. 0000000

3.5. Difference Between Gauss-Krüger Projection and UTM Projection

Differences between the UTM Projection and the Gauss-Krüger Projection:

- ① The central meridian scale factor differs: the UTM Projection uses 0.9996, while the Gauss-Krüger Projection uses 1.

- ② The division of zones is the same, but the starting point for the zone number is different.

- ③ For mid- and low-latitude regions, the UTM Projection exhibits less distortion than the Gauss-Krüger Projection.

- ④ Western countries (such as the US, UK, Germany, and France) primarily use UTM Projection for their national basic topographic map projection, while Eastern countries (such as China, Russia, Mongolia, and North Korea) primarily use the Gaussian-Krüger projection for this

purpose.

3.6. Seven/Four Parameters

The purpose of the seven parameters is to enable conversion between two ellipsoid datums, such as the common transformation from the 80/54 geocentric coordinate system to the CGCS2000 coordinate system.

The four parameters are used for conversion between two plane rectangular coordinate systems.

The seven-parameter transformation provides a more comprehensive method for coordinate transformation, capable of handling large-scale and three-dimensional spatial transformations, whereas the four-parameter transformation is more suitable for small-scale and two-dimensional plane transformations. The choice of transformation method depends on the required accuracy, the scope, and the available parameter information. The differences between the seven parameters and the four parameters are as follows:

Feature/Type	Seven parameters (Helmert transformation)	four parameters
Definition	The seven-parameter transformation includes translation (dx, dy, dz), rotation (rx, ry, rz), and a scale factor (m).	The four-parameter transformation includes two translation parameters (dx, dy), one rotation parameter, and one scale parameter.
Application	Used for coordinate transformation in geodesy, suitable for large-scale and high-precision transformations.	Mainly used for local planar coordinate transformation where extremely high precision is not required.
Accuracy	Offers high transformation accuracy and is suitable for scenarios requiring high-precision coordinate transformation.	The transformation accuracy is relatively low, making it suitable for small-scale transformations or situations where high precision is not required.

Feature/Type	Seven parameters (Helmert transformation)	four parameters
Complexity	The transformation formula is relatively complex and requires calculating the combined effects of the Seven parameters.	The transformation formula is relatively simple and easy to implement and compute.
Applicability	Suitable for global or large-scale coordinate transformations, such as geodetic coordinate system transformations between countries.	Suitable for local area coordinate transformations, such as city or small-scale map projection transformations.

3.7. Ellipsoidal Height, Normal Height, Orthometric Height

3.7.1. Ellipsoidal height

- Usually obtained directly through GNSS measurement.
- The reference surface is the ellipsoid.
- Due to the irregularity of the Earth's ellipsoid, ellipsoidal height cannot directly reflect the actual terrain height.
- Ellipsoidal height is also referred to as geodetic height.

3.7.2. Orthometric height

- It is determined using geodetic methods, taking into account the normalization of the Earth's gravity field.
- The reference surface is the quasi-geoid.
- It is used for national or regional elevation systems and, compared to ellipsoidal height, is closer to the actual terrain elevation.

The 1985 elevation system in our country uses orthometric height.

3.7.3. Orthometric height

- This is the most intuitive concept of elevation, but it is also the most complex to measure.
- The reference surface is the level surface.
- It requires consideration of the local gravity field and terrain undulations at the ground point.

- It is commonly used in engineering construction, land surveying, and related fields.

3.7.4. Elevation anomaly

The height ξ from the quasi-geoid to the Earth's ellipsoid.

Formula: $\xi = H - h$, where H is geodetic height and h is Orthometric height.

3.7.5. Elevation correction grid

Some countries and regions provide an elevation correction grid file, typically in TIF/TIFF format, where the XY and attribute values represent longitude, latitude, and elevation anomaly values. If provided by the client or available for download from certain websites, it can be used directly to obtain the final Orthometric elevation values.

4. Gaussian Fundamentals

Since 2023, 3D Gaussian technology has been the most popular 3D reconstruction method. Its comparison with traditional manual modeling and MESH is as follows:

4.1. 3D Gaussian Principle

3D Gaussian principle: The scene is represented using deformable Gaussian spheres, which are projected onto the screen and rendered with depth blending. The process consists of four steps:

(1) Initialization: SFM is used to calculate image poses (some can leverage the rapid pose estimation of Laser SLAM), resulting in a sparse point cloud—these are the Gaussian seed points.

(2) Forming the initial Gaussian spheres

(3) Continuously add, remove, and modify Gaussian spheres, comparing them with images; eventually, dense Gaussian spheres are formed. This is the most time-consuming step.

(4) Leverage the transparency property of Gaussian spheres for rapid rendering into 2D images.

4.2. 3D Gaussian Applications Fields

Film production, virtual production, VR/AR, digital twins, autonomous driving, cultural heritage, AIGC, and other fields.

4.3. Difference Between 3D Gaussian and Traditional Modeling

For 'fast + lightweight + realistic' results, choose 3D Gaussian.

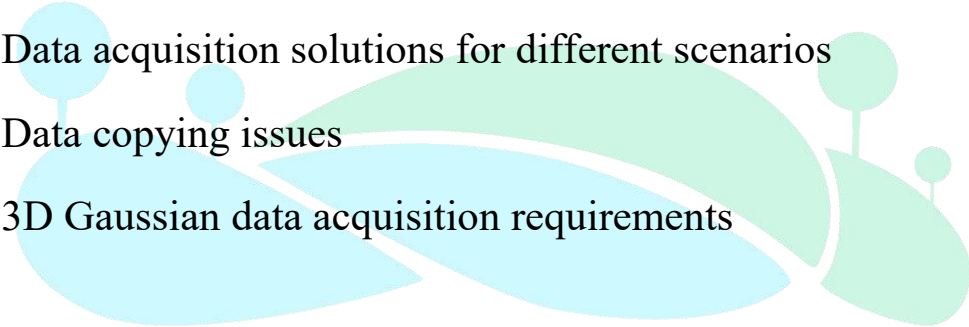
For 'surveying-grade accuracy,' use Traditional Photogrammetry.

For 'full control + ultra-high accuracy,' manual modeling is still required.

Dimension	3D Gaussian Splatting (3DGS)	Traditional Photogrammetry	Manual Modeling
Workflow	Take photos → AI auto-generates millions of Gaussian ellipsoids	Multi-angle drone photos → aerial triangulation → dense matching → mesh/texturing	Artist manually creates points, edges, faces, sculpts, and textures
Data Size	Small (~1/10 of photogrammetry, ~1/50 of manual)	Large (TB of raw imagery + GB of OSGB/mesh)	Largest (high-precision models can exceed 100 GB)
Production Time	Minutes to hours	Hours to days (triangulation + modeling + cleanup)	Days to weeks or months
Automation Level	Fully automatic, one-click result	Semi-automatic, heavy manual cleanup required	Fully manual
Geometric Accuracy	cm–dm, slightly blurred edges	cm level, sharp edges	mm level, manufacturing-grade precision
Detail Capture	Excellent: thin wires, leaves, railings naturally wrapped	Moderate: weak-texture/fine structures often have holes	Fully controllable—add as much detail as desired
Materials & Lighting	Built-in, jointly optimized	Requires separate texture baking	Needs full PBR pipeline & manual tuning
Real-Time Rendering	60–100 FPS on mid-range GPUs	Large scenes need LOD, high GPU cost	Polygon explosion; heavy LOD or baking required
Post-Editing	Hard: can only add/remove Gaussians, can't "pull points"	Medium: mesh editable but topology breaks easily	Easy: vertices, edges, faces fully editable
Dynamic Updates	Supports incremental updates in minutes	Requires re-flight and full pipeline	Requires remodeling
Hardware Requirements	Training: 8–12 GB VRAM; viewing: 4 GB VRAM	Drone + high-end workstation	High-end workstation + artist time
Typical Use Cases	VR/AR, digital twins, film previs, rapid city updates	Surveying, smart-city basemaps, cadastral mapping	Game heroes, film close-ups, industrial design, 3D printing

02 Data Acquisition

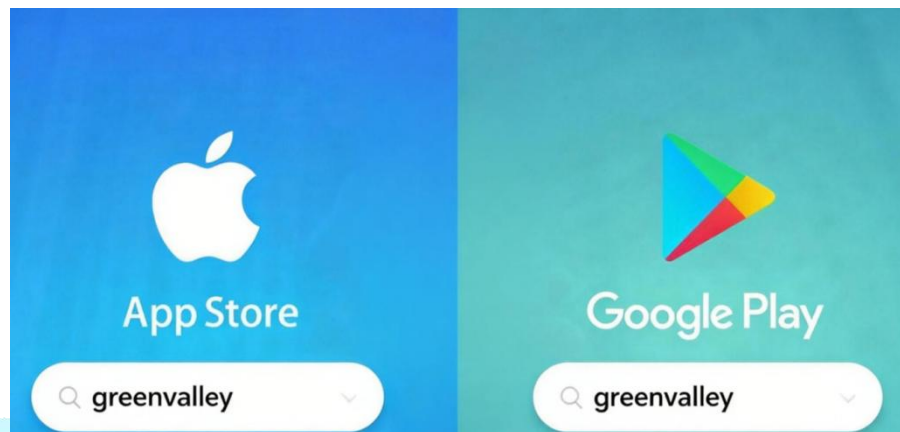
This chapter introduces:

- Software and hardware requirements before data acquisition
 - General data acquisition process and precautions
 - Data acquisition solutions for different scenarios
 - Data copying issues
 - 3D Gaussian data acquisition requirements
- 

5. Software/Hardware Requirements Before Data Acquisition

5.1. Acquisition control software requirements

The acquisition control software provided by GreenValley offers practical features such as project management, RTK configuration, virtual base station setup, and real-time point cloud browsing. Download links are shown in the figure below (left: iOS, right: Android).



Requirements for acquisition control software on mobile devices

iOS: iOS 12 or later, with an A10 processor or above on Apple phones or tablets.

Android: Minimum system requirement is Android 8, with at least 6GB RAM and a built-in GPS module.

Ensure the app is updated to the latest version before data acquisition. You can upgrade online using the Upgrade button.

5.2. Acquisition Device Requirements

5.2.1. Storage and Power Requirements for the Data Acquisition Device

Before starting data acquisition, ensure at least 5% of storage space remains available (some devices will display a red button indicator when space is below 5%).

Before starting data acquisition, ensure the battery level is above 30%.

5.2.2. Firmware Requirements for the Data Acquisition Device

Before starting data acquisition, ensure the firmware is updated to the latest version. In the 'Device Management' interface, click 'Firmware Upgrade' and follow the app prompts to upgrade

online.

If you encounter issues during firmware upgrades, please contact technical support or after-sales service for targeted assistance.

5.2.3. Appearance requirements for the acquisition unit.

- The camera lens and laser emitter must be clean; use professional cleaning tools to wipe them.
- Is the GNSS securely connected locally?

5.3. 4G Network Requirements

For areas requiring RTK data collection, ensure that 4G service is functioning properly (when using the factory-provided 4G SIM card, you can scan the RTK module's QR code for verification) and that the signal is strong.

For areas where RTK data collection is not required, this requirement can be disregarded.

5.4. Camera Precautions

- ① Ensure that the camera surface is free of stains.
- ② For general surveying and mapping needs, set the camera frequency to medium. For Gaussian acquisition, set the camera frequency to high

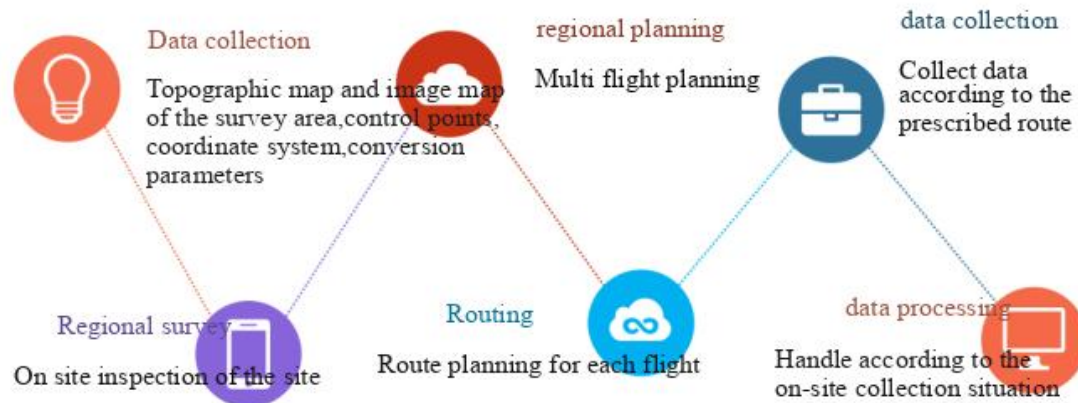
5.5. Preparation Before Connecting the SE

The SE supports two connection methods: Wi-Fi and Hotspot. For the Hotspot connection, please note the following:

- ① After the device has fully started (when the power and acquisition indicators are steady), open the app.
- ② Whenever possible, use a dedicated mobile phone for data acquisition to avoid disconnection caused by incoming calls.
- ③ Whenever possible, turn on the Hotspot just before use. Turning it on too early will drain the phone's battery, and some phones may even disable it by default to save power.
- ④ Disable power saving mode; Hotspot is the first option optimized in power saving mode.
- ⑤ Ensure that the phone can access the internet normally.
- ⑥ For iOS devices, enable 'Maximum Compatibility.'
- ⑦ To collect Gaussian data, set the camera frame rate to the maximum.

6. General workflow and precautions for data acquisition

6.1. General workflow for data acquisition



(1) Data Collection

Mainly collect topographic maps, images, control points, coordinate systems, and transformation parameters to help us understand the survey area in advance, plan routes, and facilitate later coordinate transformation.

(2) Field Reconnaissance

Conducting a field survey before measurement allows us to better plan and optimize the scan path and the method for collecting control points.

(3) Area Planning

If multiple flight sorties are required, they should be planned according to the actual conditions of the area. In principle, there should be a trajectory overlap of 2 to 5 meters between sorties.

(4) Route Planning

Route planning should prioritize optimal data quality. Plan routes according to the following principles:

The method of route planning varies for each scenario; refer to the next section.

(5) Data acquisition

During data acquisition, different scenarios have different requirements; refer to the next section.

(6) Data Processing

This includes SLAM computation, GCP integration, data stitching, coordinate transformation, and more.

6.2. Loop closure conditions during route planning

- ① If there is no GNSS, no GCP, or weak GNSS, loop closure should be planned.
- ② If GNSS and GCP are available throughout the process, loop closure is not required.
- ③ For weak feature scenarios such as tunnels, pipelines, and culverts, back-and-forth loop closure is not recommended.

6.3. Impact of GNSS environment on the acquisition route

If the GNSS environment is poor, it can be assessed by the number of RTK fixed solutions and the real-time error displayed by RTK. If using PPK, assessment can be based on the PDOP value. Generally, a value less than 3 is ideal; if it exceeds 3, loop closure should be considered.

6.4. When setting up your own base station

When using a self-established base station for PPK processing, the following rules must be observed:

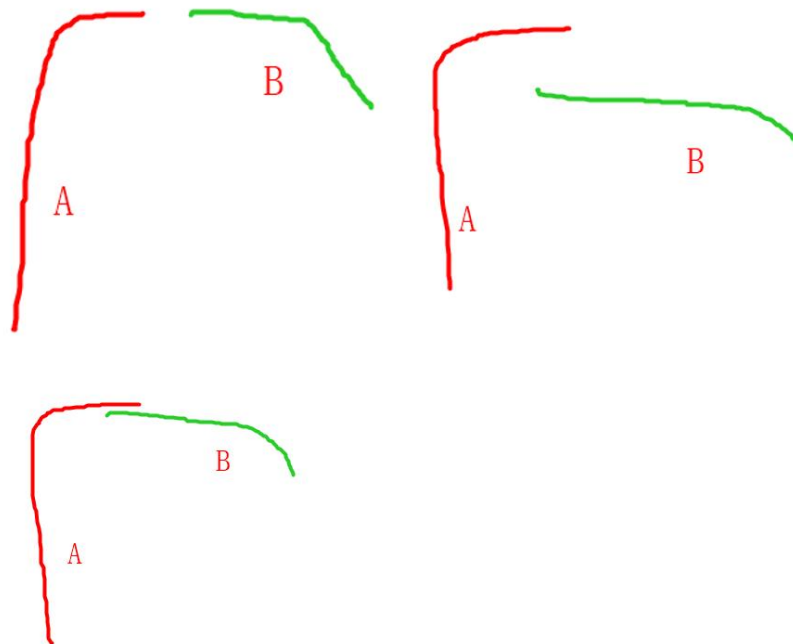
The base station must be set up at a known point, with the following requirements for the base station location:

- ① The ground foundation should be stable to facilitate base station setup and operation.
- ② The field of view should be open, and the elevation angle of obstacles around the field of view should be less than 10° to 15° , to ensure that satellite signal reception is not affected.
- ③ There should not be any objects nearby that strongly reflect satellite signals (such as large buildings);
- ④ Keep away from high-power radio transmitters (such as TV stations, radio stations, microwave stations), and maintain a distance of at least 200 meters; Keep away from high-voltage transmission lines and microwave radio signal transmission channels, and maintain a distance of at least 50 meters.
- ⑤ The base station must cover the 10 minutes before and after data acquisition.

6.5. When multiple flights are required for data acquisition

For multiple flight sorties, the data trajectories should overlap, with at least 2–5 meters of overlap and the distance between trajectories within 3 meters; In the following three images, the

first image shows no overlap, the second image shows trajectories that are too far apart, and the third image shows the correct overlap.



6.6. Time limits for data acquisition

When not collecting images, there is no strict time limit; however, larger raw data sets may place pressure on memory and disk resources during office work.

When collecting images,

① For the H120/H300, it is recommended to use time-lapse photography for data collection and to keep the duration of a single flight sortie within one hour.

Whether time-lapse photography is supported depends on the firmware program. Please consult sales or technical support.

② The V100/H120 (older models) only support video recording mode, and the duration of a single flight sortie should be kept within one hour.

③ There is no time limit for recording on the O1-LITE; however, considering device heat dissipation and office work computing efficiency, it is recommended to keep recording within 90 minutes and to monitor the remaining storage space.

④ Files from the O2 Series are generally large, so please ensure sufficient storage space.

The recommended acquisition duration is within 90 minutes.

6.7. Relationship between data acquisition time and file size

Different raw data formats and compression methods result in varying file sizes. The following table shows the relationship between data size and recording time (for reference only).

Device	10-minutes recording	Image acquisition frequency
SE	4.3GB	Medium
SE	5.2GB	high

6.8. Ground Point Acquisition Precautions

If ground data needs to be collected, do not keep the laser emitter parallel to the ground.

When going down the stairs, aim the laser as downward as possible, but do not exceed 60°

7. Data acquisition schemes and precautions for different scenarios

Different scenarios have different SLAM Features, GNSS environments, and geographic Features, requiring different acquisition strategies.

7.1. Park, city, and architectural area environments

SLAM features in parks, cities, and architectural environments are relatively abundant. When planning acquisition routes, follow these principles:

- ① The principle of loop closure should be implemented as described in Section 6.2.
- ② For GNSS environments, refer to Section 6.3 when planning acquisition routes.
- ③ If you encounter large vehicles, you may step aside slightly so that the laser emitter scans static objects. Wait until the large vehicle has passed before continuing the measurement.
- ④ When approaching a traffic light, try to slow down in advance to ensure you pass through the intersection while the light is green.
- ⑤ If collecting data with GNSS and you encounter a scene under trees, try to avoid walking under the trees.
- ⑥ If there are buildings on one side and it is necessary to capture the building facade, it is recommended to scan the building at a 45° angle.
- ⑦ To reduce the burden of office work, accompanying personnel should remain 5 to 10

meters behind the data acquisition personnel.

- ⑧ When marking GCP points, avoid having people gather around the data collector.

7.2. Road environment

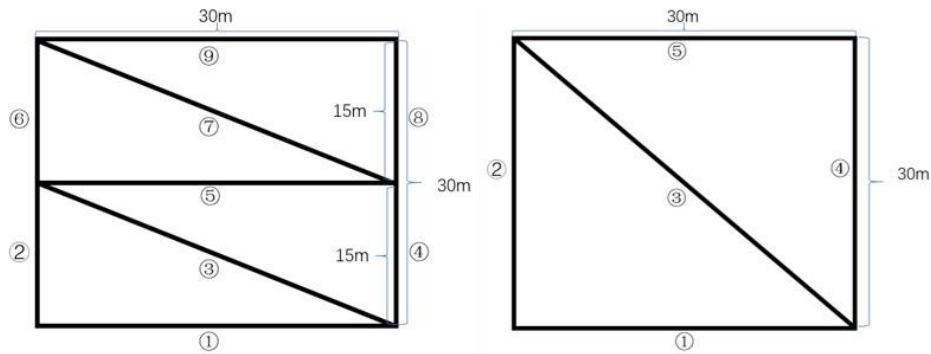
Road environments are generally open, so it is recommended to use H300 or O2 Series devices for data acquisition to increase the likelihood of successful mapping.

- ① The principle of loop closure should be implemented as described in Section 6.2.
- ② For GNSS environments, refer to Section 6.3 when planning acquisition routes.
- ③ When collecting road data, it is recommended to use equipment with GNSS to ensure operational accuracy.
- ④ If you encounter large vehicles, you may step aside slightly so that the laser emitter scans static objects. Wait until the large vehicle has passed before continuing the measurement.
- ⑤ When approaching a traffic light, try to slow down in advance to ensure you pass through the intersection while the light is green.
- ⑥ When encountering two-way lanes, since it is uncertain whether a loop can be completed, try to use GNSS-enabled data acquisition to ensure the data remains consistent.
- ⑦ If collecting data with GNSS and you encounter a scene under trees, try to avoid walking under the trees.
- ⑧ To reduce the burden of office work, accompanying personnel should remain 5 to 10 meters behind the data acquisition personnel.

7.3. Forestry environment

For example, consider a 30 m × 30 m forestry sample plot:

Plan the path for the data collection area. The purpose of path planning is to capture all information about the trees while minimizing data redundancy. For a 30 m × 30 m sample area, if the trees are dense, use the path planning method shown on the left in the figure below; if the trees are sparse, use the method shown on the right:



Path planning (Dense trees: left; Sparse trees: right)

Please note the following points during forestry data acquisition:

- ① If the grass is too tall and the laser emitter cannot scan any features at the point marking location, do not perform point marking.
- ② Point marking is not recommended in forested areas; instead, use GCP point marking to introduce absolute coordinates.
- ③ When encountering grass holes or shrub tunnels, try to avoid passing through them. You may end the data acquisition at this point and start a new project, or clear vines from the path to prevent obstructions during acquisition.
- ④ The GNSS environment under the forest canopy is poor. If a GNSS fixed solution is obtained, check for any point jumps (which can be viewed in the profile). If any are found, it is recommended to delete them.
- ⑤ When encountering steep slopes or inclines, avoid jumping down; it is recommended to slide down instead.
- ⑥ Maximize the number of loop closures to prevent tree trunk stratification.

7.4. Tunnel environment

SE has a relatively weak adaptability to tunnels, and it is not recommended to conduct data collection in tunnels with weaker characteristics.

7.5. Mine environment

- ① During data acquisition, always face directly forward to allow the laser emitter to scan a larger area.
- ② When you encounter a dead end or an impassable road inside a mine tunnel and need to turn around, you can use the method shown in the diagram below (reverse hand grip, exit

backwards).



- ③ When performing GCP point marking, avoid having people gather around the operator.
- ④ If you encounter a steep downhill, point the laser emitter in the direction of the slope.
- ⑤ When large vehicles or crowds approach, slowly scan static objects with the laser emitter and wait for the vehicles or people to pass before continuing data collection.
- ⑥ In environments with water mist, which can generate a large number of noise points for the laser emitter, operations should be stopped.

7.6. Indoor environment

- ① It is best to open the door in advance and avoid moving it during measurement.
- ② When entering, first perform a comprehensive scan of the house from the outside, then slowly enter through the door.
- ③ When encountering relatively narrow spaces (around 1 meter), try not to enter; simply scan from the doorway.
- ④ During indoor data collection, avoid crowds and people following behind to ensure the laser emitter can effectively scan the floor, walls, and other point clouds, thereby improving data quality.
- ⑤ Maximize the number of indoor loop closures whenever possible.
- ⑥ For multi-level spaces, loop closures should also be established between floors, which can be achieved via stairwells or dual staircases.
- ⑦ If you are concerned about misalignment between multiple floors, you can use control points in an assumed relative coordinate system for correction. Generally, the pillars and wall corners between floors are consistent on the coordinate plane, and the elevation is usually fixed. During internal processing, substitute GCP point marking.

- ⑧ When using the backpack kit for scanning, walk with bent knees in low spaces.

7.7. Power gallery environment

The data acquisition requirements for power utility corridors are similar to those for tunnels. However, completed power utility corridors generally have more features, but two points should still be noted.

- ① Do not turn around in place.
- ② When performing point marking, stand up and squat down slowly.

In some projects, absolute coordinates may be required. In such cases, external control points should be introduced, and coordinates substituted using the traverse method with a total station.



7.8. Precautions for data acquisition in open environments

Open environments are only supported by O2 Series devices.

7.9. Precautions for Gaussian data acquisition

- ① Ensure the lens is clean and free of stains.
- ② Set the camera to a high frame rate. For the H Series, select video recording mode; for the O Series, select the highest available camera frame rate.
- ③ Record wherever your focus lies, and ensure the lens is properly aimed.
- ④ Distinguish between key targets and non-key targets. Prioritize data collection for key targets, and collect data for non-key targets as secondary. Proper prioritization will effectively

improve collection efficiency.

⑤ Different scales require different distances. For standard data acquisition, maintain a distance of 2–3 meters between the device and the object. For smaller key targets, you may move closer, such as 0.5–2 meters (please slow down the acquisition speed accordingly). For larger targets with fewer features, you may increase the distance, for example, more than 3 meters.

⑥ Pay particular attention to specific, independent objects, such as sculptures or ornaments. Point the lens toward the target and use the surround acquisition method—circle around the object multiple times, collecting data from various angles and distances. This is the simplest and most effective approach.

⑦ For certain planar objects, such as bulletin boards, billboards, or signs; Orient the camera toward the target, and proceed to collect data using an 'S', 'spiral', or '2'-shaped path.

⑧ In areas with significant changes in lighting, such as transitioning from indoors to outdoors, you should reduce your walking speed.

For additional data collection precautions, please refer to the documentation.

<https://mp.weixin.qq.com/s/zKSYalydXYcgO6IsO0XO0w>

03 Data Processing Section

This chapter introduces:

- High-precision SLAM computation software requirements
- Explanation of each parameter in SLAM computation software
- Common error messages and solutions
- Solutions for issues related to accuracy, noise, point cloud thickness, and colorization
- Error messages and their solutions

8. High-precision SLAM processing software configuration requirements

Memory (RAM): 32 GB or above. If using 2mm high-density mode or outputting Gaussian results, it is recommended to have 64GB or more memory.

Central Processing Unit (CPU): Intel® Core™ i5/i7 recommended; eight-core, sixteen-thread

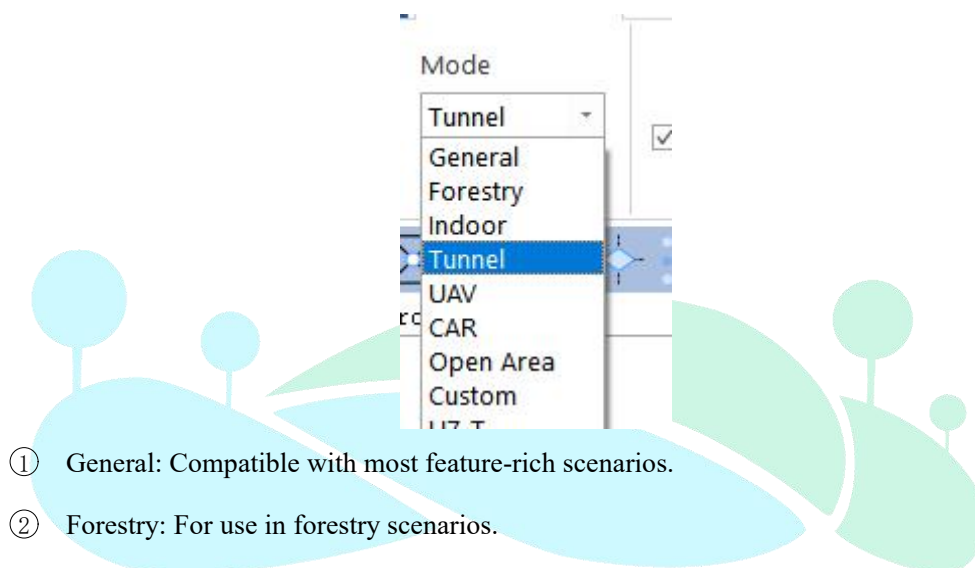
processor with single-core performance of 4 GHz or higher.

Hard Drive: For data processing, an SSD solid-state drive is recommended, with a transfer speed of 100 MB/s or higher.

Display Adapter: NVIDIA discrete graphics card recommended, with at least 8 GB of video memory.

Operating System: Microsoft Windows 7 (64-bit), Microsoft Windows 8 (64-bit), Microsoft Windows 10/11 (64-bit), or Windows Server 2012 or later.

9. Meaning of each mode



① **General:** Compatible with most feature-rich scenarios.

② **Forestry:** For use in forestry scenarios.

③ **Indoor:** For use in indoor scenarios.

④ **Tunnel:** For use in tunnel scenarios; calculation speed is 30% to 40% slower than General. For the O2 Series, if tunnel data is collected, this mode should be selected.

⑤ **Drone:** Used with the airborne kit; calculation speed is approximately 30%–40% slower than the general mode.

⑥ **Vehicle-mounted:** Used with the vehicle-mounted kit; calculation speed is approximately 30%–40% slower than the general mode.

⑦ **Custom:** User-defined processing settings.

10. Data processing time

Office work processing time is influenced by various factors such as the field data acquisition environment and path planning; it is not a purely linear proportional relationship. In general, the more complex the acquisition scenario and the greater the number of loop closures, the longer the

algorithm detection time.

Currently, under the general mode output: the ratio of office work processing time to field acquisition time is approximately 3–4.

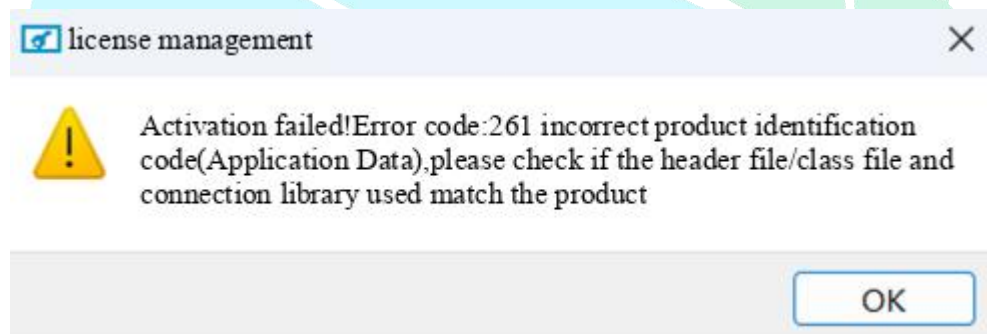
In high-density output mode: The ratio of office work processing time to field acquisition time is approximately 4–6.

In 2mm high-density output mode: The ratio of office work processing time to field acquisition time is approximately 8–10.

To accelerate computation, you can upgrade to a higher-performance CPU, increase memory, use a better graphics card, and utilize a high-speed SSD.

11. Processing software activation issues

MLS software activation error 261: Delete the C:\ProgramData\BitAnswer folder and reactivate.



12. Common error messages and solutions in slam.log

12.1. Bag file read error!

Meaning: Error reading bag file.

Possible causes: ① Copy error or file corruption; ② Packet error, which is very unlikely.

Solution: ① Recopy the file; ② Click the repair icon in the app.

12.2. SLAM results may be incorrect

Meaning: SLAM computation failed.

Possible causes: ① Too few features; ② Turning too quickly; ③ The number of features

from dynamic objects exceeds those from static objects.

Solutions: ① Place feature objects; ② Re-acquire the data; ③ Reduce the feature filtering size; ④ In General settings, increase the minimum distance.

12.3. Processing memory is insufficient

Meaning: Insufficient memory.

Possible causes: ① Low memory, less than 32GB; ② Insufficient computer resources due to other programs occupying memory; ③ Data is being computed directly from a USB drive.

Solutions: ① Use a computer with larger memory, at least 32GB (64GB or more recommended); ② Close other programs that are using computer resources; ③ Restart the computer; ④ Avoid computing directly from data stored on a USB drive.

12.4. Processing error: vector<T> too long

Meaning: File read error.

Possible causes: ① Disk speed is too low; ② SLAM computation is performed directly on the USB drive; ③ Disk space is critically low.

Solution: ① Avoid performing computations directly on the USB drive; ② Free up disk space.

12.5. Rename lidata file error: xxxx

Meaning: Failed to rename the lidata file.

Possible cause: Occurs during loop closure optimization and stitching when the lidata file is being accessed by another program.

Solution: ① Release the lidata file from use.

12.6. Build lidata failed

Meaning: Failed to create the lidata file.

Possible cause: Often occurs at the end of SLAM computation, during the point cloud output step, most likely due to insufficient disk space.

Solution: Ensure that at least twice the size of the original data is available as reserved disk space.

12.7. Lidar scan range too small!

Meaning: Laser ranging detected as too short.

Cause: The laser cover was not removed at the start of data acquisition.

Solution: ① Re-acquire the data; ② Use settings to skip the period when the laser cover was on.

12.8. Loop closure process failed.

Meaning: Loop closure detection failed.

Possible causes: ① Disk speed is too low; ② SLAM computation is performed directly on the USB drive; ③ Disk space is critically low.

Solution: ① Avoid performing computations directly on the USB drive; ② Free up disk space.

12.9. Get video file paths failed!.

Meaning: Video file does not exist.

Cause: ① The wrong video file was copied; ② The video file is missing.

Solution: Copy the correct and complete video file.

12.10. Failed to decode image_time.bin

Meaning: Failed to parse image_time.bin.

Cause: The image_time.bin file in the Built-in Camera folder is missing or incomplete.

Solution: Copy or download the camera data again.

12.11. Camera bin files not same, please check!.

Meaning: There is an issue with the number of camera bin files, which does not match the original records.

Cause: The number of fisheye camera bin files in the camera directory is inconsistent, or some bin files are missing.

Solution: Copy or download the camera data again.

12.12. The number of image timestamps is less than the number of image frames!

Meaning: The number of timestamps from the INSTA camera is less than the number of recorded images.

Cause: ① Errors within the INSTA camera itself, such as frame loss or timestamp confusion.

Solution: ① First, observe the final result. If there are no issues with colorization, you may

ignore this. ② If there are issues, you need to reacquire the data and avoid starting the camera manually.

12.13. Move distance insufficient!

Meaning: Intermediate SLAM results were not generated.

Cause: ① IMU and LiDAR times are not synchronized; ② Initialization failed; ③ No data from IMU.

Solution: ① and ③ are device issues; for ②, re-initialize.

12.14. GPS Time is out of sync with trajectory time, please check the trajectory!

Meaning: The time difference between the POS and LiDAR is too large (1 day).

Cause: ① The base station and rover station times do not match; ② The device's GPS and LiDAR are not synchronized.

Solution: ① Confirm whether the base station and rover station files match; ② Contact after-sales support.

12.15. * gap**

12.15.1. laser gap

Meaning: LiDAR data loss

Cause: LiDAR data was lost during device acquisition.

Solution: ① The data loss app will prompt you; reacquire data in the field. ② Check whether the cables are properly connected. ③ For other situations, please contact after-sales support.

12.15.2. imu gap

Meaning: IMU data loss

Cause: IMU data was lost during device acquisition.

Solution: ① The data loss app will prompt you; reacquire data in the field. ② Check whether the cables are properly connected. ③ For other situations, please contact after-sales support.

12.16. GCP initial transform error, please check GCP pairs

Meaning: Excessive initial GCP matching error.

Cause: Excessive initial error between the control point and point marking.

Solution: Check the error prior to GCP. ① Reorganize the matching relationship between point marking and control point. ② Alternatively, check whether X and Y have been entered

incorrectly.

12.17. GNSS file doesn't exit

Meaning: The *.gnsstraj file does not exist.

Cause: The *.gnsstraj file is missing, damaged, or has been modified.

Solution: Recalculate PPK or import the RTK file.

12.18. Re-output lidata failed

Meaning: Point cloud output failed.

Cause: ① The previous lidata file is missing or damaged; ② Insufficient disk space.

Solution: Ensure sufficient disk space and re-export.

13. Poor point cloud accuracy

13.1. Poor relative accuracy

The concept of relative accuracy here is consistent with that described in Section 1.9. Generally, there are two factors that affect relative accuracy.

(1) Number of environmental features

The more environmental features there are, the better the relative accuracy. Relative accuracy is generally higher in park and city scenarios, but is poorer in tunnels with weak features.

(2) Loop closure factors.

Since accumulated error must be eliminated through loop closure, the more loop closures there are, the higher the relative accuracy.

If you encounter poor relative accuracy, you can try increasing features or adding more loop closures to resolve the issue.

13.2. Poor absolute accuracy

Poor absolute accuracy can occur in three types of data acquisition: GCP, RTK, and PPK.

When checking absolute accuracy, it is necessary to review the point file. At this stage, the first step is to confirm the reliability of the check points with the client. For example:

① **Which coordinate system are the check points in?**

② **Are the elevation systems consistent?**

③ **Ensure that the differential source used for collecting check points is the same as that used during SLAM data acquisition.**

13.2.1. Low accuracy after GCP adjustment.

① Check the spacing of control points. Generally, spacing within 100 meters is optimal and can achieve accuracy within 5 cm.

② Check the distribution of control points. Control points should be evenly distributed throughout the survey area and must not be arranged in a straight line.

③ Insufficient scene features.

④ X and Y are reversed (X corresponds to East, Y corresponds to North).

If the distance between control points is too great, you can improve accuracy by conducting additional field surveys to supplement control points, and then incorporating them through GCP point marking.

13.2.2. Accuracy is relatively poor when using RTK.

① The number of RTK fixed solutions is low.

② Insufficient scene features.

③ When a checkpoint is located in an area where RTK cannot be fixed for an extended distance—generally more than 150 to 200 meters—it is difficult to maintain accuracy within 5 cm.

④ RTK false fixes are common, for example, between tall buildings.

⑤ The ionosphere can be quite active; avoid periods of high activity.

If there are few RTK fixed solutions, you can improve accuracy by conducting additional field surveys to supplement control points, and then incorporating them through GCP point marking.

13.2.3. Accuracy is relatively poor when using PPK.

① There are few PPK fixed solutions.

② Insufficient scene features.

③ The base station setup does not meet the requirements (refer to Section 5.4 for details).

④ There are many false PPK fixed solutions, for example, between tall buildings.

⑤ The base station is too far from the survey area (including cases where a virtual base station is set up too far from the survey area), exceeding 15 km.

⑥ When a checkpoint is located in an area where PPK cannot be fixed for an extended distance—generally more than 150 to 200 meters—it is difficult to maintain accuracy within 5 cm.

If there are few PPK fixed solutions, accuracy can be improved by conducting additional field surveys to establish control points and incorporating them through GCP point marking.

14. Layering issues

14.1. When no GNSS data is collected

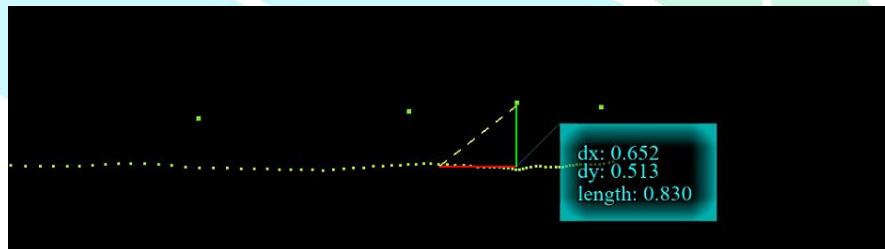
When data is collected without GNSS, layering is usually caused by loop closure issues or cumulative SLAM errors. The following solutions are recommended:

- ① Re-collect the data and increase the number of effective loop closures.
- ② Use the manual loop closure editing function in MLS.
- ③ If the above methods are ineffective, resolve the issue by adding control points (these can be absolute coordinates or assumed coordinates).

14.2. When GNSS data is collected

When GNSS is available, layering issues generally do not occur unless there are a large number of false GNSS fixed points. The following methods can be used to resolve this:

- ① Delete the false fixed solutions, which can be identified by viewing the profile. Generally, GNSS fixed points differ significantly from SLAM.

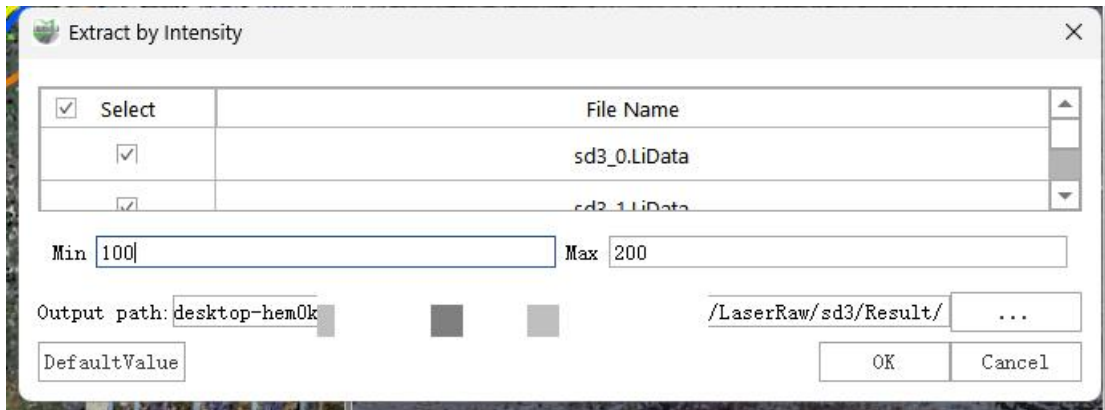


- ② If the layering issue still cannot be resolved, it may be due to the lack of a fixed solution in that area. This can be addressed by using point marking to introduce GCPs as appropriate.

15. Noise issues

15.1. Noise from water

When it rains or in areas with puddles, water surface noise points often appear. These noise points tend to cluster, and standard denoising algorithms are generally ineffective at removing them. The intensity values of these water noise points are typically 0, so you can filter by intensity and remove points with an intensity of 0 or below.



15.2. Noise from dust

Dust noise points can generally be removed directly using noise filtering.

15.3. Noise from reflections

Glass, marble, and smooth metal surfaces can cause mirror image noise points.

Mirror noise points are generally difficult to remove through denoising or intensity extraction and should be deleted manually.

15.4. Noise from tree trunks

To remove trunk noise points, use the **Forestry Mode** and apply the default filtering.

15.5. Noise from light sources

During indoor data acquisition, certain lighting may generate noise points, which can only be removed manually.

15.6. Noise from dynamic objects

Use dynamic object filtering.

16. Point cloud thickness issues

The thickness of different reflective media in the point cloud varies (**when unfiltered**). Generally, the thickness of asphalt pavement and walls is within 1–2 cm (the thickness of walls increases with height and distance), while grass and gravel surfaces tend to be slightly thicker.

If further thinning of the point cloud is required, you may use smoothing filters.

17. Colorization issues

① It is highly likely that the camera calibration parameters are incorrect. You can calibrate the camera using MLS, then obtain the IMCAB.T file and import it into the device to update the

camera calibration parameter file (refer to the MLS user manual).

② If the issue is caused by the camera itself, please contact technical support or after-sales service for assistance.

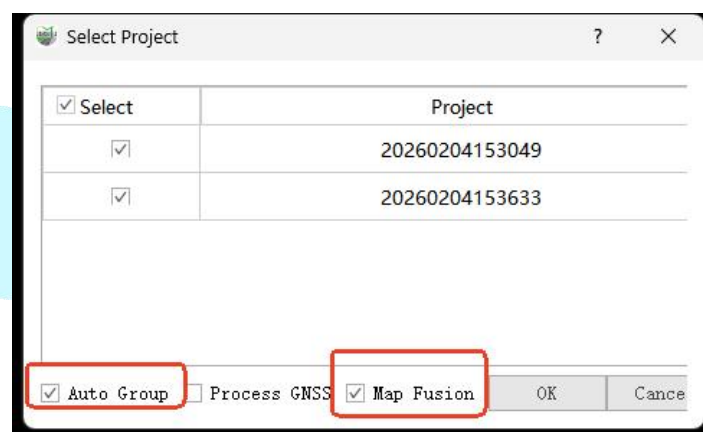
18. Continuous scanning issue

18.1. External conditions for continued scanning

Continuation scanning occurs at the end of the previous station and the beginning of the next station. Usually, we initiate continuation scanning directly at the end of the previous station while keeping the equipment stationary;

18.2. How to Process Continuous Scanning Data

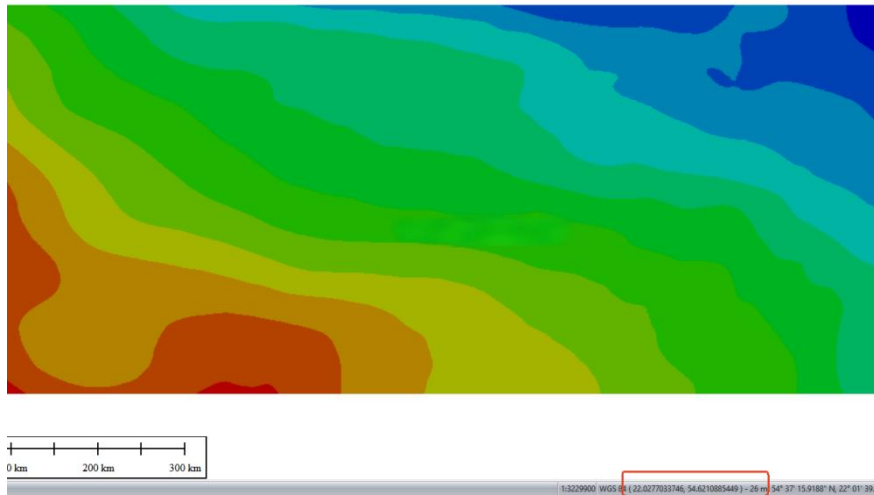
MLS will automatically perform data merge for the resumed scanning project, without user intervention. When the LISLAM file is imported into MLS, **Auto Group** and **Map Fusion** will be automatically checked, and finally, click "Start".



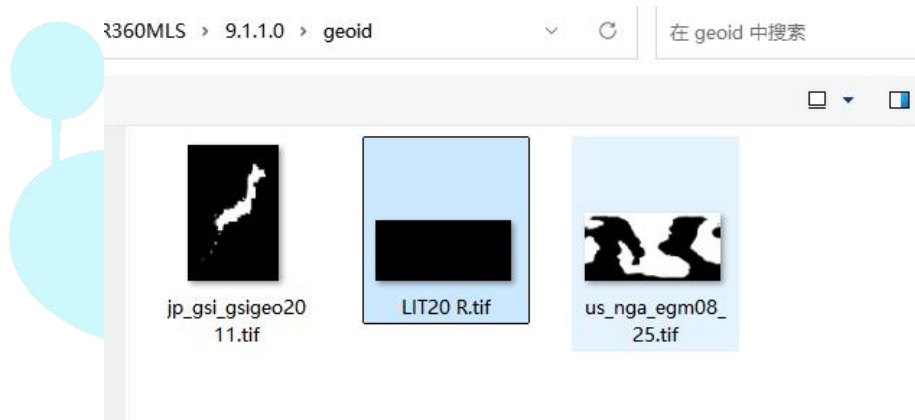
19. The application of the geoid correction file failed

The geoid correction file is usually used to convert geodetic height (ellipsoidal height) to normal height.

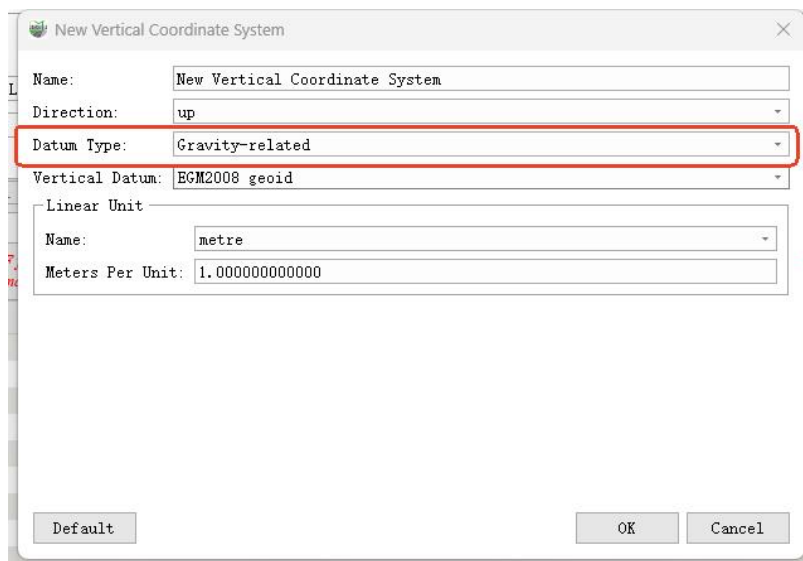
Format requirements for geoid correction files: TIF/TIFF format, latitude and longitude format



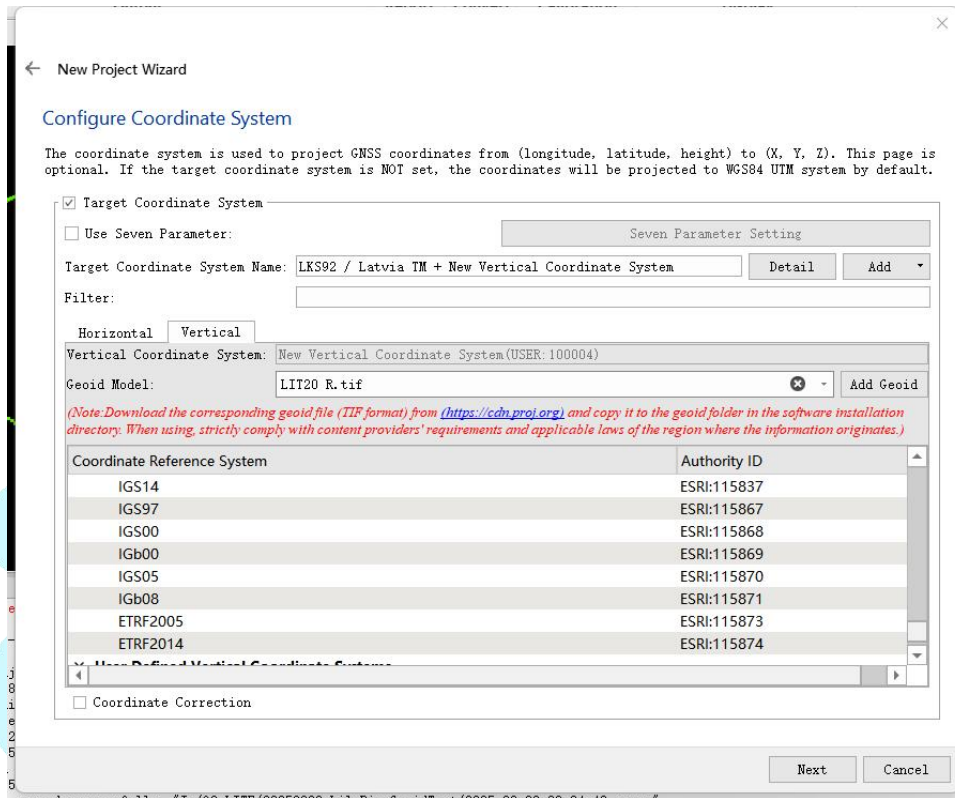
① The corrected file needs to be saved to the geoid folder under the MLS installation directory



② Add a vertical coordinate system based on gravity



③ Add tiff



After the completion of the new project, check whether the ellipsoidal height and the grid elevation are consistent. If they are not, it indicates that the application has been successful

```
# Version: 1.2
# FileType: GnsTrajectory
# Description: Week,WeeklySecond,Longitude,Latitude,EllipsoidHeight,StdNorth,StdEast,StdHeight,AmbiguityStatus,Quality,NumberSatellites,UtcDate,UtcTime,GridX,GridY,GridZ
2483,203287.000,56.9507418772,24.2233923334,30.000,0.013,0.008,0.021,Fixed,1,43,2026-01-27,08:28:07,513588.520,311924.961,9.099
2483,203288.000,56.9507418626,24.2233923334,30.000,0.013,0.008,0.021,Fixed,1,43,2026-01-27,08:28:08,513588.520,311924.961,9.099
2483,203289.000,56.9507418545,24.2233923781,30.000,0.013,0.008,0.021,Fixed,1,43,2026-01-27,08:28:09,513588.523,311924.960,9.093
```

04 Common Device Issues

This chapter introduces:

- Battery Maintenance
- Camera-related Issues
- Device-related Issues



20. Battery Maintenance/Charging Issues

20.1. Storage Requirements

Storage temperature requirements: Recommended to store in a dry environment at 22°–30°C. Do not use or store below -20°C or above 60°C. Keep away from strong static electricity, magnetic fields, and heat sources (such as inside a car under direct sunlight).

Storage charge requirements: If not used for an extended period, discharge to 40% ~ 65% (neither fully charged nor fully discharged); Before taking the battery on a flight, be sure to discharge it to below 5%. Ensure you are away from fire sources during discharge.

If not used for an extended period: Recharge and discharge the battery approximately every three months to maintain battery activity.

20.2. Charging Requirements

- (1) The smart battery must be charged using the dedicated charger officially provided by Digital Greensoil. Digital Greensoil will not be responsible for any consequences resulting from the use of chargers not officially provided by Digital Greensoil.
- (2) When charging, place the battery and charger on a cement floor or another surface free of flammable or combustible materials. Please monitor the charging process to prevent accidents.
- (3) After LiDAR operation is complete, please check the battery temperature before charging. If the battery is at a high temperature, forced charging can severely damage its lifespan. It is recommended to wait until the battery cools to room temperature before charging. Charging in an ideal temperature environment (5°C~40°C) can significantly extend the battery's service life.
- (4) After charging is complete, please disconnect the charger from the battery. Regularly inspect and maintain the charger, and frequently check the battery's appearance and all its components. Do not use alcohol or other flammable agents to clean the charger. Do not use a charger that is already damaged.

21. Device-side issues

21.1. The LiGrip app on Apple phones displays a 'no network connection' error when connecting to the device.

You need to manually enable the 'Local Network' permission for the LiGrip app in the phone's APP settings.



21.2. Apple phones report network anomalies

Solution: Enable the phone's location function.

21.3. How to view device SN, firmware version, and other information from the data

The device.info file located at 'Temp\SLAMProcess\temp\device.info' displays key device information.

① Device firmware version ② Device type ③ Selected mask file name ④ Device SN number ⑤ Synchronization status

```
DeviceString: "1.3.0LiGripDGCPRO_RHG50C"
Version: "1.3.0"
Type: "H120"
Rotation: "180"
Direction: "180"
Mask: "rotmask"
SN: "GVWHGH2210B031"
Sync: "SyncProcessed"
RotType:1
```